## III. Ultrashort-Wave Antennas

Transmitting and receiving antennas for meter waves do not differ greatly from short-wave antennas. The main element of antennas for the radiation or reception of meter waves is a wire of length $\ell = \frac{\lambda}{2}$. To obtain directional radiation, an antenna in the form of a half-wave wire is sometimes placed at the focus of a cylindrical paraboloid made from a copper sheet (Figure 354). This type of antenna has sharp directivity in the plane perpendicular to the axis of the radiating wire. To obtain sharp directivity in the horizontal and vertical planes, the radiating wire is [illegible] at the focus of a paraboloid of revolution. To obtain sharp [illegible] ultrashort-wave antenna is sometimes made in the form of a cophasal horizontal antenna similar to a short-wave antenna.

For obtaining one-sided (forward instead of forward and back) directivity from a cophasal array, the system of wires, representing a passive mirror, is replaced in [illegible] designs by a solid screen in the form of a copper or aluminum sheet. [illegible] antenna, called the wave channel (Figure [illegible]), is used [illegible] practice. Wire 1, a half-wavelength long, is the radiating element, connected to the transmitter by a feeder. Wire 2, which is slightly more than a half-wavelength long, is used as a reflector. Wires 3, 4, and 5 are slightly less than a half-wavelength long and therefore the currents flowing ~~in them~~ lag in phase [illegible] the current in wire 1. As a result, the energy radiated is concentrated in a direction [illegible] wires 3, 4, and 5. These directing wires, placed in front of [illegible] antenna, are called directors. The number of directors may vary from 3 to 10, depending upon the degree of directivity desired.

Meter-band antennas are usually fed by a concentric feeder. Since the concentric is an unbalanced system, a coupling network must be used when it is used to feed a symmetrical antenna. A type of coupling network for changing a nonsymmetrical feeder 1 to a symmetrical one is shown in Figure 356. The concentric line branches at point A. The distance AB is one half-wavelength in order to obtain a potential at point B having a 180° phase shift with respect to the potential at point A.

Besides a half-wave, Pistol'kors folded dipole antenna (Figure 357) is also used. There will be current nodes at points A and B of this antenna, i.e, there will be a phase shift of 180° so that the currents in both radiating wires will always flow in the same direction.

The power radiated by the antenna is

$$P_\Sigma = \frac{1}{2}(2I)^2 R_\Sigma$$

where $R_\Sigma$ = 73 Ω, i.e., the radiation resistance of a half-wavelength [illegible]

Thus,

$$P_\Sigma = \frac{1}{2} I^2 292,$$

from which it follows that the radiation resistance of the folded dipole, which determines the input resistance of the antenna, is considerably higher than that of a half-wave dipole. The increased input resistance of the antenna [illegible] ly matched with the characteristic impedance of the supply feeder to obtain [illegible] wave flow in the feeder.

The transmitting antenna must be elevated to a considerable height in order to obtain high field intensity [illegible]

[illegible] antennas are for the most part a system of [illegible], but when we move to decimeter and centimeter waves, [illegible] must be used to a greater degree instead [illegible] elements [illegible] antennas [illegible] radiation and reception of decimeter and centimeter waves, but for the latter waves, special types are also used, such as horn antennas, slot antennas, metallic lenses, and dielectric antennas. The latter antennas are not used for longer wavelengths.

The horn antenna is a radiating system which is a natural extension of a waveguide for the transfer of electromagnetic energy into space (Figure 258).

The horn antenna has sufficiently sharp directivity and can be used over a wide band of frequencies given the proper horn dimensions. A deficiency of the horn antenna is its relatively large size in comparison with an antenna having a parabolic reflector.

A slot antenna is an antenna in the form of a hole in a surface made of a good conductor. If a number of slots are made in one of the walls of a waveguide, electromagnetic energy will be radiated from these holes, which thus may be regarded as unique antennas. The form of the slots will depend upon the field structure within the wave guide. This antenna is equivalent in directivity of radiation to an antenna consisting of a grounded wire placed along the axis of a ring. The slot antenna is sometimes made in the form of narrow rectilinear slot about a half-wave long. Sharp directivity can be obtained by spacing several slots a certain distance apart.

The structural advantage of slot antennas is the absence of projecting parts. The phase velocity in a wave guide is greater than the velocity of propagation of energy in free space. This can be used to devise sharply directional antennas, called lenses. The lens antenna is a series of wave guides of comparatively short length placed in such a way as to create many parallel paths for the flow of electromagnetic energy.

The relative position and length of the wave guides is selected so that the ends of all wave guides lie in one plane and the beginnings of all form some curved surface. The lens antenna is shown schematically in Figure 359, where the individual wave guides are shown in cross-section. The ends of the wave guides coincide with the y-axis, while the beginnings form some curve mn.

The operating principle of the metallic lens antenna is as follows: the electromagnetic field created by the source at the point A (Figure 359) is propagated along various paths and approaches the y-axis. The beam coinciding with the x-axis takes the shortest path; the beam directed at a certain angle to the x-axis takes a longer path, but part of its path lies within a wave guide so that its velocity in this section is higher. The combination of all wave guides used for directing the energy from the source to the y-axis forms the antenna, a metallic lens. We can select a lens profile mn such that the phase of all oscillations reaching the y-axis will coincide and thus the energy leaving the lens will be propagated further in a parallel beam.

The time required for the motion of the energy along the path AO = a is

$$t = \frac{a}{c}$$

and must equal the time required along the path ACD = AC + CD

$$\frac{a}{c} = \frac{\sqrt{(a-x)^2+y^2}}{c} + \frac{x}{V_w} \qquad (1)$$

where c is the velocity of energy in empty space and $V_w$ is the phase velocity in the wave guide.

Designating $k = \frac{c}{V_w}$, equation (1) is easily transformed to

$$\sqrt{(a-x)^2+y^2} = a - xk,$$

and thus

$$a^2 - 2ax + x^2 + y^2 = a^2 - 2axk + x^2k^2.$$

After combining corresponding terms we obtain:

$$x^2(1-k^2) - 2xa(1-k) + y^2 = 0$$

or

$$x^2 - 2xa\frac{1}{1+k} + y^2\frac{1}{1-k^2} = 0.$$

The dependency obtained between y and x can be reduced to the form

$$\left(x - \frac{a}{1+k}\right)^2 + \frac{y^2}{1-k^2} = \frac{a^2}{(1+k)^2}$$

or finally

$$\left(\frac{x}{a\frac{1}{1+k}} - 1\right)^2 + \frac{y^2}{a^2\frac{1+k}{1-k}} = 1,$$

from which it follows that the profile sought for the lens antenna is defined by the equation of an ellipse. A horn antenna is frequently used as a source of oscillations feeding the lens antenna. If the lens antennas are made sufficiently large, a concentration of the radiated energy within an angle measured in fractions of a degree can be obtained.

Superhigh frequencies are also obtained through the use of a dielectric antenna which is a rod made from dielectric material having the form of a cone with a diameter of approximately $\frac{\lambda}{2}$ and a length of (3 – 4) $\lambda$ (Figure 360). Oscillations are excited in the rod with the help of the antenna 1 and the rod radiates oscillations only in the direction of the apex of the cone. Antennas made up of several rods are used to obtain sharper directivity. The rod is usually made from trolitul, a [German] plastic having low losses and a high dielectric constant.

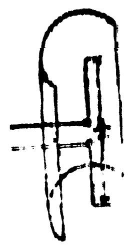

Figure [illegible]

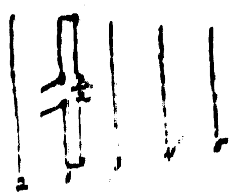

Figure [illegible]

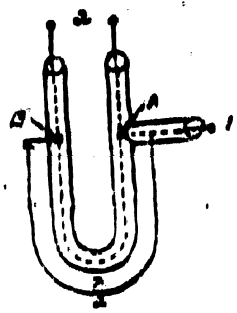

Figure 356

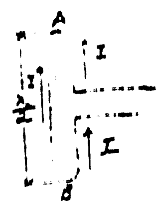


Figure 357

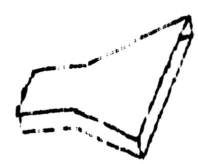

Figure 358

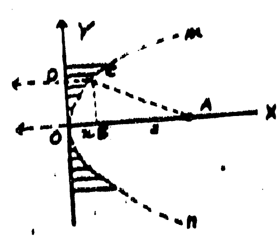


Figure 359

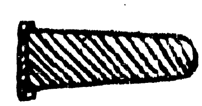

Figure 360

## IV. SHF Receivers

In the reception of ultrashort waves, we must consider a number of factors which are of relatively little importance in the reception of longer waves. The shorter the waves, obviously, the more important tube capacitances and inductances ~~of~~ leads [illegible] (filament-to-plate). With a shorter wavelength, losses in the tube and circuit increase as does the transit time. In the reception of ultrashort waves, the processes ~~occurring~~ in the receiver depend greatly upon the internal noise created in the receiver. For waves shorter [illegible] m, the minimum signal level ~~at~~ of the receiver input is determined by the internal noise level (in the absence of man-made ~~[illegible]~~ interference).

The internal [illegible] result of electron processes in the conductors and tubes.

The free electrons in each conductor are in continuous motion. As a result of [illegible], a current continuously changing in value [illegible] direction is set up in the conductor and a slight alternating voltage is developed at the ends of the conductor. The magnitude of this voltage $U_n$ in microvolts in the frequency band $\Delta f$ (expressed in kc) is given by the following equation:

$$U = \text{[illegible]}$$

where R is the resistance of the conductor (particularly, the resistance of the circuit $R = \frac{L}{Cr}$) expressed in kilohms.

Tube noise is created mainly by the shot effect. The shot effect ~~consists~~ is due to non-uniform electron emission. Emission is chaotic, i.e., the number of electrons boiled off the incandescent filament changes continuously and as a result the plate current of the tube always contains a small alternating component.

With respect to the noise voltage applied to the grid of the tube, the triode is equivalent to some resistance R whose value (in kilohms) depends upon the transconductance (in milliamps per volt): $R = \frac{2.5 - 3}{S}$.

The noise resistance of a pentode is approximately 3 to 5 times that of a triode.

A sufficient signal-to-noise ratio must be obtained for normal receiver operation, and therefore sufficiently close coupling must be used between the input ~~device~~ circuit and the antenna feeder. The input ~~device~~ circuit for a meter-wave receiver does not differ greatly from the input device for a receiver of longer waves. In going to decimeter waves, however, the oscillatory circuit with lumped capacitance and inductance is generally replaced by a concentric feeder [illegible] approximately a quarter wavelength long short-circuited at the end. A variation of the input circuit for reception of decimeter waves is shown in Figure 362. The short-circuited feeder used as the oscillatory system of the input circuit is loaded by the tube capacitance $C_t$. The resonance condition for the input device is that the inductive reactance of the feeder be equal to the capacitive reactance of the tube

$$Z_c \tan \alpha l = \frac{1}{\omega C_t}$$

which will be satisfied if the length of the feeder $l$ is made slightly less than a quarter wavelength.

The input impedance of the rf amplifier has not only a reactive component provice by the tube capacitances but also an active component, which increased attenuation of the input tuned circuit. For ultrashort waves, current will flow in the grid circuit of the amplifier tube even if the voltage on the grid is negative ($U_g < E_g$) at any moment of time. The presence of grid current even for a high negative grid bias $E_g$ is explained by the fact that the transit time from filament to plate is commensurable with the period of oscillations for ultrashort waves. For a sharp increase of grid potential, the number of electrons moving from filament to grid will be at the first instant greater than the number of electrons going from the grid to the plate. For a sharp decrease of grid potential, the number of electrons moving to the grid from the filament will be at the first instant less than the number of electrons continuing to move from the grid to the plate. Because of the disparity in the number of electrons moving to the grid and leaving from it at the first instant after an abrupt change of grid potential, variable charges will be induced in the grid, causing a current in the grid circuit independent of the ratio between $U_g$ and $E_g$. This grid current coincides in phase with the alternating grid voltage $U_g$ and thus determines the active component of the tube's input impedance.

The second reason for the appearance of an active component in the tube's input impedance for ultrashort waves is the voltage drop created by the alternating component of the plate current $I_1$ across the inductance of the cathode lead $L_f$ (Figure 363):

$$U_g = I_g \frac{1}{j \omega C_{g-f}} + I_1 j \omega L_f .$$

Substituting in this expression $I_1 = S U_g$, we find

$$\frac{U_g}{I_g} = Z_g = \frac{1}{j\omega C_{g-f} + \omega^2 L_f C_{g-f} S}$$

from which it follows that the active input conductance of the tube increases as the square of the frequency shunting the oscillatory circuit of the input device. Consequently, the transfer ~~factor~~ constant and the selectivity of the input ~~device~~ circuit will decrease ~~with~~ sharply as the waves become shorter. The amplification factor and selectivity of the rf amplifier will also obviously decrease in amplifying higher frequencies since the load in the plate circuit of the tube will shunt the input conductance of the tube in the following stage to a greater degree.

A circuit with lumped constants is ordinarily used as a plate load for ~~the~~ an rf amplifier operating in the meter band. A concentric feeder is generally used in the amplification of decimeter waves.

Most shf receivers are designed for reception of only one wavelength or a narrow band of wavelengths, which simplifies the oscillatory system in the plate circuit of the tube.

Triodes are frequently used for rf amplification in order to decrease the internal noise level. Grounded-grid amplification (Figure 364) is used to eliminate the danger of self-excitation.

Consideration of the equivalent circuit of a grounded-grid amplifier (Figure 365) ~~permits us to~~ establishes that the amplitude of the ac component of the plate current is

$$I_1 = \frac{(\mu+1)U_g}{R_i + Z}$$

and the input voltage is $U_2 = I_1 Z$.

Considering that $R_i \gg Z$ and $\mu \gg 1$,

we find the amplification factor $K = \frac{U_2}{U_g} = SZ$

and the input impedance of the grounded-grid amplifier

$$Z_g = \frac{U_g}{I_1} = \frac{U_g Z}{I_1 Z} = \frac{U_g Z}{U_2} = \frac{Z}{K} = \frac{1}{S}.$$

Thus, the amplification factor of the grounded-grid amplifier does not differ from that of the usual amplifier, but its input impedance is considerably less, which is the defect of this circuit. The danger of self-excitation with a grounded-grid amplifier is less than that with an ordinary amplifier, because the feedback element in this circuit is not the plate to grid capacitance but the smaller plate to filament capacitance.

Grounded-grid triodes are used for amplification of meter and decimeter waves.

~~As the waves become shorter the amplifier~~

As the wavelength becomes shorter, the amplification factor of the rf amplifier decreases.

Present-day ultrashort-wave receivers are as a rule the superheterodyne type. In centimeter-band receivers, rf amplification is not used because ~~up to the present~~ tubes with a noise level low enough to provide sufficient amplification in this wave band have not been developed at this time.

The noise resistance of a tube increases with the number of grids employed. Because of their high internal noise and considerable interelectrode capacitances, multigrid tubes are not used for frequency conversion in the ultrashort-wave band. A cathode-coupling circuit (Figure 366) is often used for frequency conversion in the meter band. The advantage of this circuit is the ~~low~~ loose coupling between the output of the rf amplifier and the oscillator circuit (through the grid to filament capacitance of the pentode), while retaining ~~heavy~~ close coupling between the grid circuit of the mixer tube and the oscillator. The resistor $r$, shunted by the capacitor $C$, is connected in the cathode circuit to provide fixed bias on the control grid of the pentode.

Diodes are used for the most part for frequency conversion in decimeter band receivers because they provide high input impedance and a low noise level.

In the reception of centimeter waves, a crystal detector (pyrite-steel, zincite-graphite, and others) is used for frequency conversion. As an input in centimeter band recievers, a resonator containing a crystal detector (Figure 367) is used. The conductor of the concentric feeder which connects the coupling transformer with the antenna is terminated in the resonator by a small coupling loop for exciting oscillations with the frequency of the signals received $\omega_1$; the feeder connecting the resonator with the oscillator is also terminated in the resonator by a coupling loop for exciting oscillations in the resonator with the oscillator frequency $\omega_2$. Thus, the crystal detector will be in an alternating field with frequencies $\omega_1$ and $\omega_2$, and, as a result, a voltage of the intermediate frequency $\omega_3 = |\omega_1 - \omega_2|$ will appear in the detector circuit. The i-f voltage is also applied by means of the concentric feeder to the input of the i-f amplifier.

A special electron tube, called the reflex klystron, is used as an oscillator in the centimeter band. The klystron is a tube in which velocity modulation of the electrons is employed. The idea of velocity modulation for purposes of generating ultrashort waves was first proposed by Professor D. A. Roshanskiy. Let us consider the purpose of the electrodes of the reflex klystron (Figure 368). The purpose of the filament and cathode is to create a store of free electrons. A positive potential is applied to the first grid 1 in order to accelerate the electrons toward the following electrodes. A positive voltage is also applied to the second grid 2 to obtain a high uniform velocity. An alternating voltage is applied to grids 2 and 3. The electrons entering the space between grids 2 and 3 will obtain high velocity if at the given instant the potential of the third grid is greater than the potential of the second grid. Electrons entering the space between grids 2 and 3 at an instant when the potential of grid 3 is less than that of grid 2 will move with reduced velocity after leaving the grid. Thus a process of velocity modulation is developed in the space between grids 2 and 3.

A negative dc potential is applied to electrode 4, called the reflector, and consequently electrons are repelled from the reflector into the space between grids 2 and 3. Electrons moving with high speed after grid 3 will lose their velocity in direct proximity to the reflector and will then return to grid 3. Electrons moving with low speed after grid 3 will rapidly lose their velocity in the retarding field of the reflector and will return to grid 3 simultaneously with electron traveling the longer path up to the reflector and back.

Thus, velocity modulation is the reason for the bunching of electrons around grid 3. The bunches of electrons approaching grid 3 through definite time intervals will induce alternating potentials in grids 2 and 3.

The use of a klystron as an oscillator is shown in Figure 369. Grids 2 and 3 form the resonator. The electrons, velocity modulated in the resonator, enter the retarding field of the reflector and return again to the resonator, sustaining oscillations in it. A coupling loop is introduced into the resonator to transfer the oscillations obtained to the mixer through a concentric feeder.

E-N-D

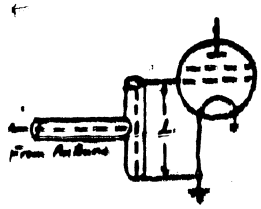


Figure 362

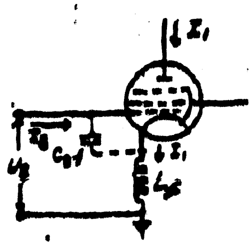

Figure 363

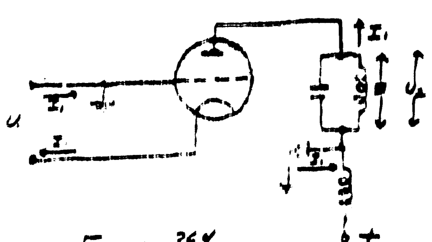

Figure 364

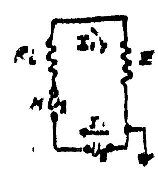

Figure 365

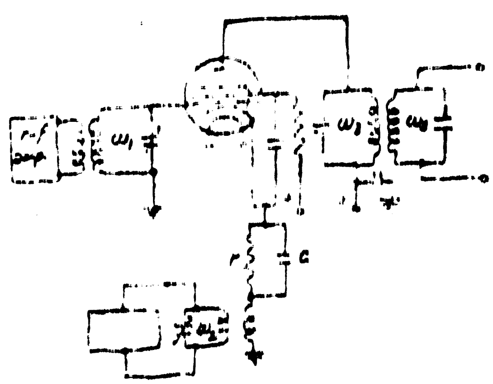


Figure 366

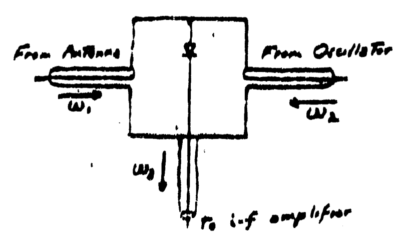


Figure 367

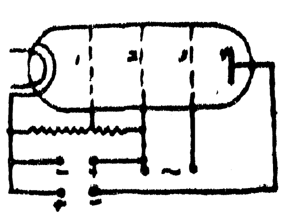

Figure 368

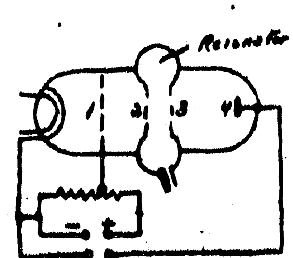


Figure 369